

Latest Maastrichtian foraminiferal assemblages from the Husów region (Skole Nappe, Outer Carpathians, Poland)

M. ADAM GASIŃSKI and ALFRED UCHMAN

Institute of Geological Sciences, Jagiellonian University, Oleandry Str. 2a, PL-30-063 Kraków, Poland;
adam.gasinski@uj.edu.pl; alfred.uchman@uj.edu.pl

(Manuscript received August 25, 2008; accepted in revised form December 18, 2008)

Abstract: The Ropianka Formation (also known as the Inoceramian Beds) in the marginal part of the Skole Nappe (Husów region, the Gaj section) contains abundant, diverse and well preserved assemblages of Maastrichtian planktonic and benthic foraminiferids, assigned to the middle-upper part of the Gansserina gansseri Zone and to the Abathomphalus mayaroensis Zone. The composition of the assemblages indicates fluctuations of organic matter flux to the marginal part of the Skole Basin floor in the studied interval. The studied taxa are typical of the “transitional zone” between the Tethyan and the Boreal domains. The disappearance of planktonic foraminifers in the uppermost part of the section and appearance of some agglutinated taxa (*Rzehakina fissistomata*; abundant *Conglophragmium irregularis* and *Glomospira charoides*) points to a Paleocene age.

Key words: Maastrichtian, flysch, transitional zone, paleoecology, biostratigraphy, foraminiferids.

Introduction

Terminal Maastrichtian foraminiferal assemblages in the Flysch Carpathians are represented by mostly poorly diagnostic benthic agglutinated taxa. The foraminiferal zones based on them (Geroch & Nowak 1984; Olszewska 1997) are broad in duration. As a consequence a precise stratigraphy of this interval is very difficult, and determination of the K/T boundary is imprecise. Exceptionally, some taxa of the youngest Cretaceous planktonic foraminiferal *Abathomphalus mayaroensis* Zone have been found in a few sections of the Subsilesian Unit (Gasiński et al. 1999, 2001) and the Skole Nappe (see chapter **Micropaleontological analysis**).

Very rich assemblages of planktonic and benthic foraminifers of youngest Maastrichtian age occur in flysch sediments of the marginal thrust sheet in the Skole Nappe, SE of Rzeszów in the Husów region (Fig. 1). Their description and interpretation are the main aim of the paper.

The biostratigraphy of the Cretaceous in the study area is so far poorly recognized, without modern micropaleontological research. Such abundant, very diverse and well preserved Maastrichtian planktonic foraminiferal assemblages are very rarely found in the Polish Flysch Carpathians (Gasiński et al. 1999, 2001, 2003). Commonly, only some index taxa are listed but not illustrated. For the first time in the Skole Unit, the planktonic foraminiferal assemblage allow the recognition of recently proposed latest Cretaceous biozones. Moreover, the microfauna of the Skole Unit contributes to our understanding of migration “gates” between the Boreal and Tethyan biogeoprovinces (Gasiński 1997, 1998; Marcinowski & Gasiński 2002). The marginal part of the Skole Unit of the Polish Carpathians was located near the Boreal-Transitional domain (Kollmann & Zapfe 1992) in proximity to the so-called Lviv Gate (Marcinowski & Gasiński 2002). Therefore, micropaleontological data from

this area are very important for reconstructions of the Late Cretaceous plankton paleobiogeography.

Geological setting

The Skole Nappe SE of Rzeszów has been studied since the 19th century. Tietze (1883) distinguished the Ropianka Beds in the vicinity of Albigowa and ascribed all the flysch deposits SE of Rzeszów to the “older Tertiary”, and Hilber (1885) assigned them to the Neocomian. Friedberg (1900) also distinguished the Ropianka Beds at Albigowa and Husów. Wdowiarz (1936, 1949) characterized the lithostratigraphy and tectonics of the Cretaceous and younger deposits of this area. He recognized the Inoceramian Beds (formerly known as the Ropianka Beds), subdivided them into the lower, middle and upper levels, estimated their thickness at 500 m, and dated them to the Senonian–Paleocene by analogy to other areas. They are overlain by the Eocene Variegated Shale. For a comprehensive history of research on the Ropianka Beds (latter Ropianka Formation or Inoceramian Beds) in the Skole Nappe see Kotlarczyk (1978). Bromowicz (1974) described the lithology and distinguished four lithological complexes in the Inoceramian Beds in the area SE of Rzeszów, the total thickness of which was estimated at about 400 m. Bromowicz determined that their sediments were transported from the NW. West of the study area, Malata (2001) distinguished the Fucoid Marl Member, Leszczyny Sandstone Member (Maastrichtian) and the Makówka Slump Debris (Late Maastrichtian) within the Ropianka Formation which was renamed as the Rybotycze Formation.

At first in the 19th century, the studied deposits of the Skole Nappe were named the Ropianka Beds, which were originally distinguished in the Magura Nappe (Paul 1869). Later, these deposits were called the Inoceramian Beds (Uhlig 1888;

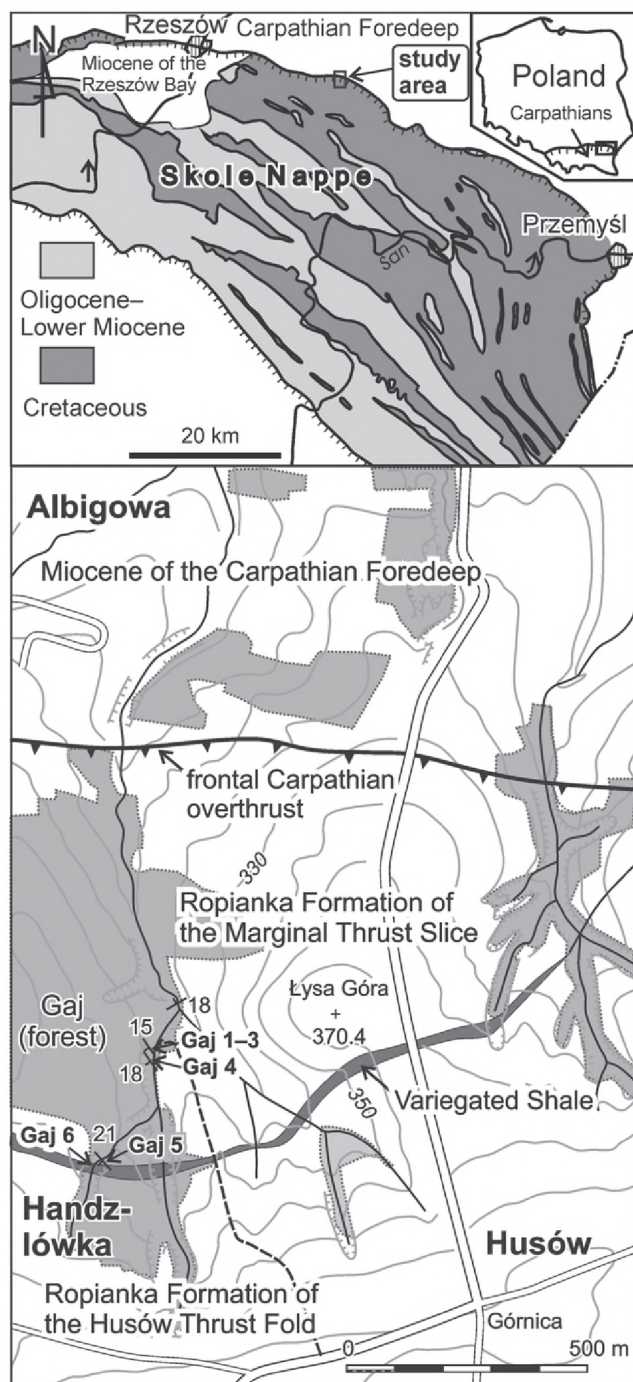


Fig. 1. Location map. Tectonic unit designation, Carpathian margin and range of the Variegated Shale after Wdowiarz (1949). Location of samples (Gaj 1, etc.) indicated.

Wdowiarz 1949). Kotlarczyk (1978) applied the oldest name to the Inoceraman Beds of the Skole Nappe and established the Ropianka Formation with its neostatotype in the Przemyśl area, which he (see also Kotlarczyk 1979, 1985) subdivided into the Cisowa Member (Turonian–Lower Campanian), Wiar Member (Lower Campanian–Lower Maastrichtian), Leszczyny Member (Lower Maastrichtian–Lower Paleocene) and Wola Korzeniecka Member (Paleocene) (Fig. 2).

This lithostratigraphic scheme was a matter of controversies (Haczewski 1986; Ślaczka & Miziołek 1995; Malata 1996, 2001) but new propositions, if present (Malata 1996, 2001), are also problematic. These problems require clarification that is beyond the scope of this study.

The oldest biostratigraphic data in the studied area come from the 19th century. Hilber in Uhlig (1883) and Grzybowski (1903) found inoceramid bivalve fragments at Husów (their Hussow) pointing to the Cretaceous. Friedberg (1901, 1903) determined the foraminifers *Dendrophrya excelsa* Grzybowski, *D. robusta* Grzybowski and *D. robusta* var. *maxima* from intercalations of sandstones and shales at Albigowa, probably from the Inoceraman Beds. Friedberg (1908) determined *Inoceramus salisburgensis* Fugger & Kastner from Husów.

The studied section occurs along the Gajowy stream, in the Gaj forest between the territories of the villages of

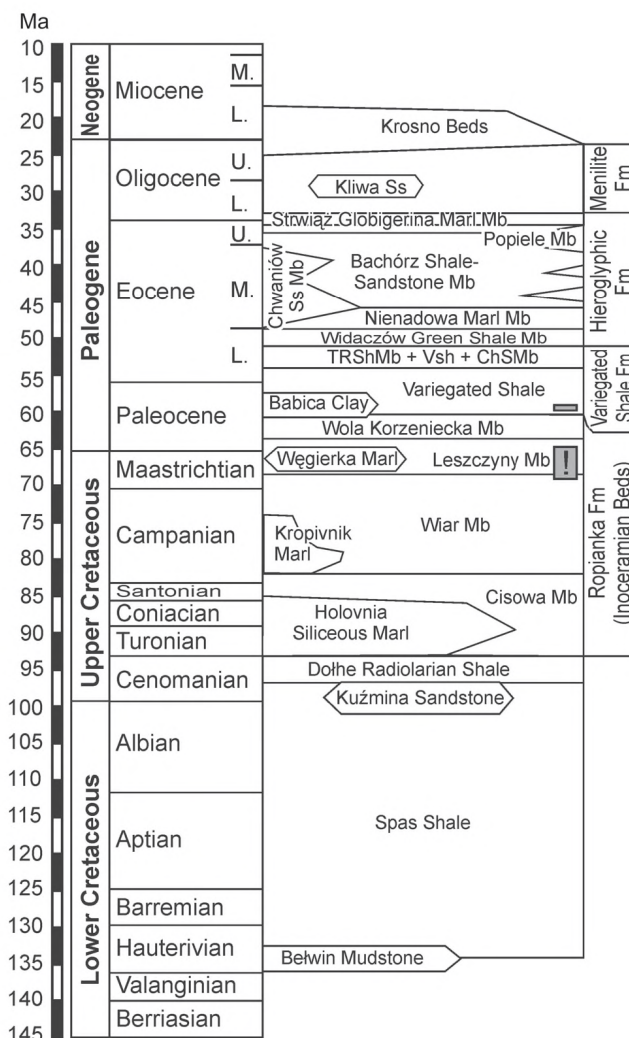


Fig. 2. Stratigraphic scheme of the Skole Nappe. Based on Kotlarczyk (1988), Rajchel (1990), Rajchel & Uchman (1998), Ślaczka & Kaminski (1998), with further corrections based on further data by Gedl (1999) and Kotlarczyk et al. (2007). The investigated interval indicated by "!". The time scale is after Gradstein et al. (2004). **TRShMb** — Trójca Red Shale Member, **VSh** — Variegated Shale, **ChSMb** — Chmielnik Striped Sandstone Member.

The studied outcrops are composed of turbiditic deposits with a great contribution of marls and marly shales intercalated with fine- to medium-grained calcareous sandstones (Fig. 3). The lower part of the studied sequence (sections A and B) contains more sandstones, with beds up to 30 cm thick. The upper part (sections C, D) contains less sandstones, with thinner beds. These deposits contain the trace fossils *Ophiomorpha rudis* (especially in thicker beds), *Chondrites targionii*, and rarely *Nereites irregularis* and *Phycosiphon incertum*. Stratigraphically, the studied depos-

Micropaleontological analysis

Biostratigraphy

Twenty five samples from the section studied area have been analysed (see: Figs. 3, 4). Some of these contain well

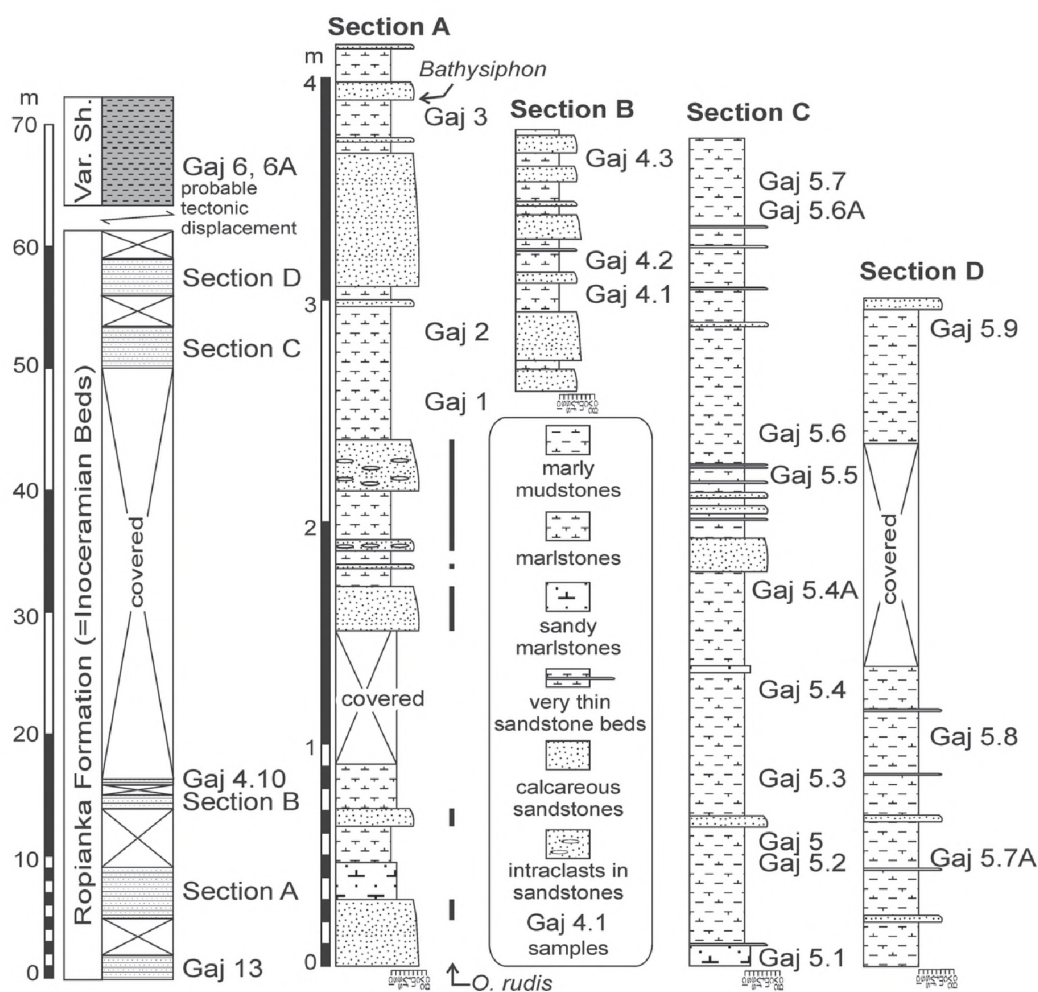


Fig. 3. Lithological column with location of the samples.

and very well preserved planktonic and benthic foraminiferids (Figs. 4, 5). The stratigraphic ranges of the index taxa point to a Maastrichtian age. The middle to upper part of the Gansserina gansseri to Abathomphalus mayaroensis standard zones were distinguished according to the zonation published by Caron (1985), Robaszynski & Caron (1995; Fig. 5). These zones have been recognized on the basis of index planktonic foraminiferids as well as characteristic foraminiferal assemblages. The Abathomphalus mayaroensis Zone is a Taxon Range Zone. It was recognized between sample Gaj 4.1, where the first appearance (FO) of *A. mayaroensis* (Bolli) is noted, and sample Gaj 5.7, where its last occurrence (LO) is observed (Fig. 5). *Gansserina gansseri* (Bolli) is not present in the analysed material, probably due to its more Tethyan paleobiogeographic preferences. Nevertheless, the stratigraphic ranges of other planktonic species, such as: *Pseudotextularia elegans* (Rzehak), *Globigerinelloides prairiehillensis* Pessagno, *Hedbergella holmdelensis* Olsson, *Globotruncana aegyptiaca* Nakkady, *G. bulloides* Vogler and *G. stuartiformis* (Dalbiez), and the absence of *Abathomphalus mayaroensis* (Bolli) in sample Gaj 1 to Gaj 4 (below its FO) points to the underlying Gansserina gansseri Zone (Fig. 4).

Abathomphalus mayaroensis is rarely noted from the turbiditic sequences of the Outer Carpathians (e.g. Liszkowa & Morgiel 1981; Gasiński et al. 2001). However, this species is never abundant and occurs in assemblages together with other planktonic species, such as *Heterohelix navarroensis*

Ehrenberg, *H. striata* (Ehrenberg), *Pseudotextularia elegans* (Rzehak), *Racemiguembelina fructicosa* (Egger), *Globigerinelloides prairiehillensis* Pessagno, *Hedbergella holmdelensis* Olsson, *H. monmouthensis* (Olsson), *Globotruncana aegyptiaca* Nakkady, *G. arca* (Cushman), *G. bulloides* Vogler, *Globotruncanella stuarti* (de Lapparent), *G. stuartiformis* (Dalbiez), *Globotruncanella havanensis* (Voorvijk), *G. petaloidea* (Gandolfi), or *Contusotruncana contusa* (Cushman) (Fig. 4). All the diagnostic species as well as some taxa which are typical of the studied foraminiferal assemblages are illustrated in Figures 7–9. Their stratigraphic ranges are reported after Robaszynski et al. (1984), Caron (1985), Robaszynski & Caron (1995), Premoli-Silva & Rettori (2002) and Premoli-Silva & Verga (2004).

Foraminiferal assemblages from sample Gaj 5.7A to sample Gaj 6A (Fig. 4) are composed mainly of agglutinated taxa, with a small admixture of calcareous benthic forms. They do not contain any planktonic taxa. Therefore, it is impossible to determine their precise biostratigraphical position to a particular biozone, however some suggestions based on composition of the agglutinated foraminiferal assemblages can be made. Samples Gaj 5.7A, 5.8 and 5.9 contain among others the agglutinated index species *Rzehakina fissistomata* (Grzybowski), which ranges from the ?Maastrichtian to the Paleocene (Kaminski & Gradstein 2005). Liszkowa & Morgiel (1981) have dated an agglutinated foraminiferal assemblage with *Rzehakina fissistomata* from the

Krasice section of the Skole Unit as Paleocene. Sample Gaj 6 does not contain index taxa, but the increased abundance of *Congolophragmium irregularis* (White) and *Glomospira charoides* (Parker & Jones) points to the Paleogene. The same concerns sample Gaj 6A, which additionally contains *Karrerulina conversa* (Grzybowski) and *K. horrida* (Mjatliuk). The higher abundance of shales in this part of the section (Figs. 3, 4) suggests a change in depositional conditions.

Abathomphalus mayaroensis (Bolli) in the Skole Nappe

Abathomphalus mayaroensis (Bolli) (formerly *Globotruncana mayaroensis* Bolli) has been recognized by Bukowy & Geroch (1957) in the K. Wójcik collection of foraminiferids from the exotic conglomerates at Kruhel Wielki near Przemyśl. Morgiel (1959) and Szymkowska (1961) mentioned the occurrence of this species in the Babica Clay. The Babica Clay is composed mostly of debris flow deposits and is dated to the Paleocene (Bukowy 1956, 1957; Geroch & Kotlarczyk 1963). It seems that *A. mayaroensis* in this unit is redeposited from Maastrichtian sediments.

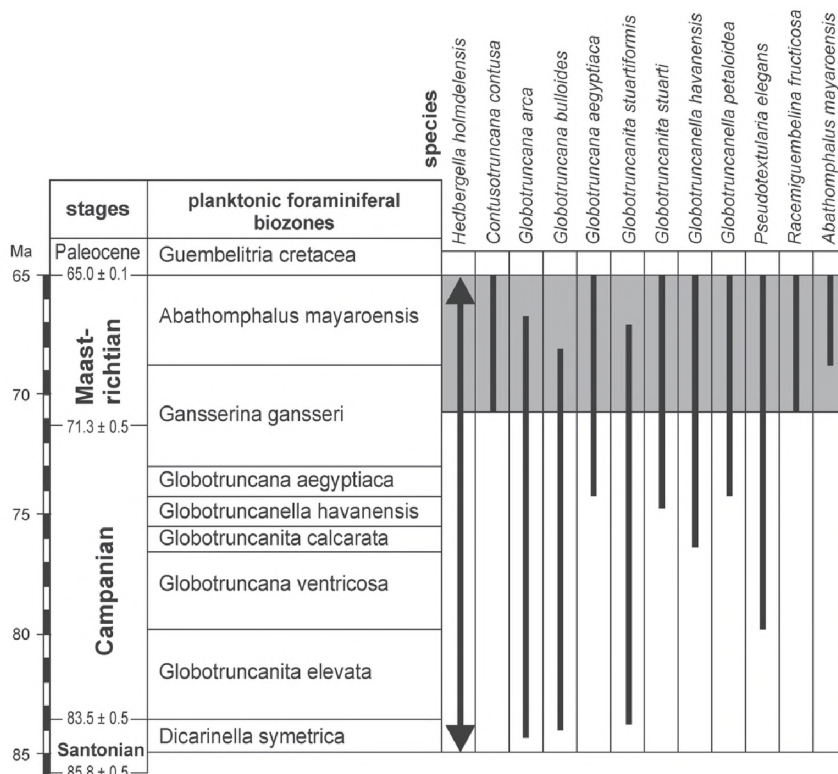


Fig. 5. Biostratigraphical ranges of the studied planktonic index taxa. Ranges of species and biozones plotted (combined) after Robaszynski et al. (1984), Caron (1985), Robaszynski & Caron (1995), Premoli-Silva & Rettori (2002) and Premoli-Silva & Verga (2004). The grey area indicates biozones recognized in the studied material.

Other findings of *Abathomphalus mayaroensis* come from the Ropianka Formation of the Skole Nappe but these observations are rarely supplemented by detailed localization. Morgiel & Żgiet (1961) mentioned *G. mayaroensis* in samples from the borehole at Dydnia (their Inoceranian Beds of the Subsilesian and Skole Units transitional zone). *Globotruncana mayaroensis* is listed among the foraminiferal assemblages of the Ropianka Formation (Inoceranian Beds) as well as those of the Węgierka Marls (upper part of the Ropianka Formation) (Gucik 1962, 1987; Gućik & Wójcik 1982; Kotlarczyk 1988). It was also listed by Bieda et al. (1963) from the Węglówka Marl and the Żegocina Marl of the Subsilesian Unit. Vialov et al. (1967) and Zhurakovsky (1971) reported findings of *G. mayaroensis* in the Ukrainian part of the Skole Nappe. Morgiel in Wdowiarz et al. (1974) mentioned it from the Cisowa IG-1 borehole. Morgiel & Liszkowa (1981) informed about relatively numerous specimens of *A. mayaroensis* within foraminiferal assemblages of the Frydek Marl-type sediments of the Subsilesian Unit as well as from the so-called Baculites Marls (an equivalent of the Węgierka Marls in the Skole Nappe).

Abathomphalus mayaroensis and associated planktonic and benthic foraminifers have also been found in the Leszczyny Member in the Przemyśl area (Kotlarczyk 1988, p. 44). Morgiel in Żyto & Zimnal (1997) noted *A. mayaroensis* from the foraminiferal association of the Smorż stream section.

Paleoecology

On the basis of washed residues of the collected samples, a quantitative analysis has been performed (Fig. 6). All specimens, including those with broken tests, were counted. For the planktonic assemblages, the parameters: planktonic/benthic ratio and epipelagic/bathypelagic ratio are considered as indicators of paleobathymetry and offshore distance (cf. Sliter 1972; Sliter & Baker 1972; Olsson & Nyong 1984; and others). Within the benthic associations, the agglutinated/calcareous benthic taxa ratio and the suspension-feeders (tubular forms such as *Rhabdammina* or *Nothia*)/other agglutinated taxa ratio were counted. These results point to the organic flux (OF) to the basin floor by turbiditic currents and to its quantitative aspect (cf. Kaminski & Kuhnt 1995; Gasiński 1998). A distinct negative correlation between an increase in planktonic and especially epipelagic species and a reduction in suspension feeders is noted (Fig. 6). Only in sample Gaj 5.4A does this relation change rapidly; planktonic species became very scarce, whereas suspension feeders dominate. This could reflect an increase in OF, which may have been caused by increased productivity or redeposition of organic matter from the shallower part of the basin due to a relative sea-level fall. However, the latter possibility is not marked by any sedimentological change, such as coarsening of sediments. The relative increase in abundance of the suspension feeder morphological group in relation to relatively scarce epipelagic taxa is observed in sample Gaj 1. Another rapid increase in suspension feeder abundance and diminishing abundance of epipelagic planktonic taxa is noted in sample Gaj 5.5. Such rapid changes among foraminiferal assemblages of samples Gaj 5.4A and Gaj 5.5 can be inter-

preted as an episode of rapid increase in sea-surface productivity (especially distinct in sample Gaj 5.4A). The increased availability of organic matter caused the rapid appearance of tubular agglutinated taxa (for the feeding strategy of foraminiferal suspension feeders see: Jones & Charnock 1985; Nagy 1992; Kaminski & Kuhnt 1995; Gasiński 1998). It should be stressed that from sample Gaj 6 (Fig. 6) agglutinated foraminiferids dominate, which indicates a drastic change in environmental conditions resulting in a change of composition of foraminiferal assemblages toward decreasing planktonic taxa. Of course, the activity of turbiditic currents taking place in the studied part of the Skole Basin strongly influenced such processes.

Discussion

Biostratigraphy

The chronostratigraphy of the *Abathomphalus mayaroensis* and Gansserina gansseri Zones has been provided by Robaszynski & Caron (1995). In their scheme, the Maastrichtian comprises the whole of the *A. mayaroensis* Zone and the upper part of the *G. gansseri* Zone. Robaszynski et al. (1984) and Caron (1985) proposed a different scheme, in which the underlying *G. aegyptiaca* and the *G. helvetica* Zones are also included into the Maastrichtian. According to the subsequent schemes by Robaszynski & Caron (1995) and Premoli-Silva & Rettori (2002), these zones belong into the upper Campanian. In the current Cretaceous Time Scale, Gradstein et al. (2004) proposed a *Racemiguembelina fructicosa* Zone situated between the *A. mayaroensis* and *G. gansseri* Zones. *Racemiguembelina fructicosa* (Egger) is present in the studied material (Fig. 8.3–6), however its occurrence together with *A. mayaroensis* (Fig. 4) does not allow us to separate the *Racemiguembelina fructicosa* Zone. *Racemiguembelina fructicosa* is rarely noted in foraminiferal assemblages of the Tethyan domain (cf. Nederbragt 1991).

It should be mentioned that the Cretaceous/Paleocene boundary (traditionally named K/T) is placed between the last occurrence of *Abathomphalus mayaroensis* (Bolli) and first abundant appearance of *Guembelitra cretacea* Cushman, which constitutes the Partial Range P0 Zone *sensu* Olsson et al. (1999) and Gradstein et al. (2004). It is located between the samples Gaj 5.7 and Gaj 5.7A of the studied section (Fig. 3), which are 3 m apart. So far, this is the most precise location of the K/T boundary in the Polish Carpathians.

Provenience of the studied planktonic assemblage

The Maastrichtian foraminiferal assemblages analysed from the Husów area (this study) and those from the Węgierka Marls of the Skole Unit (Kotlarczyk 1978; Geroch et al. 1979) display a distinct similarity. The Kropiwnik Fucoid Marl in the Wiar Member (Kotlarczyk 1978, 1985, 1988) also contains some similar species of foraminiferids, among them a few index species such as: *Globotruncana arca*, *Globotruncanella stuarti*, *Globotruncanella havanensis*, and *Contusotruncana contusa*.

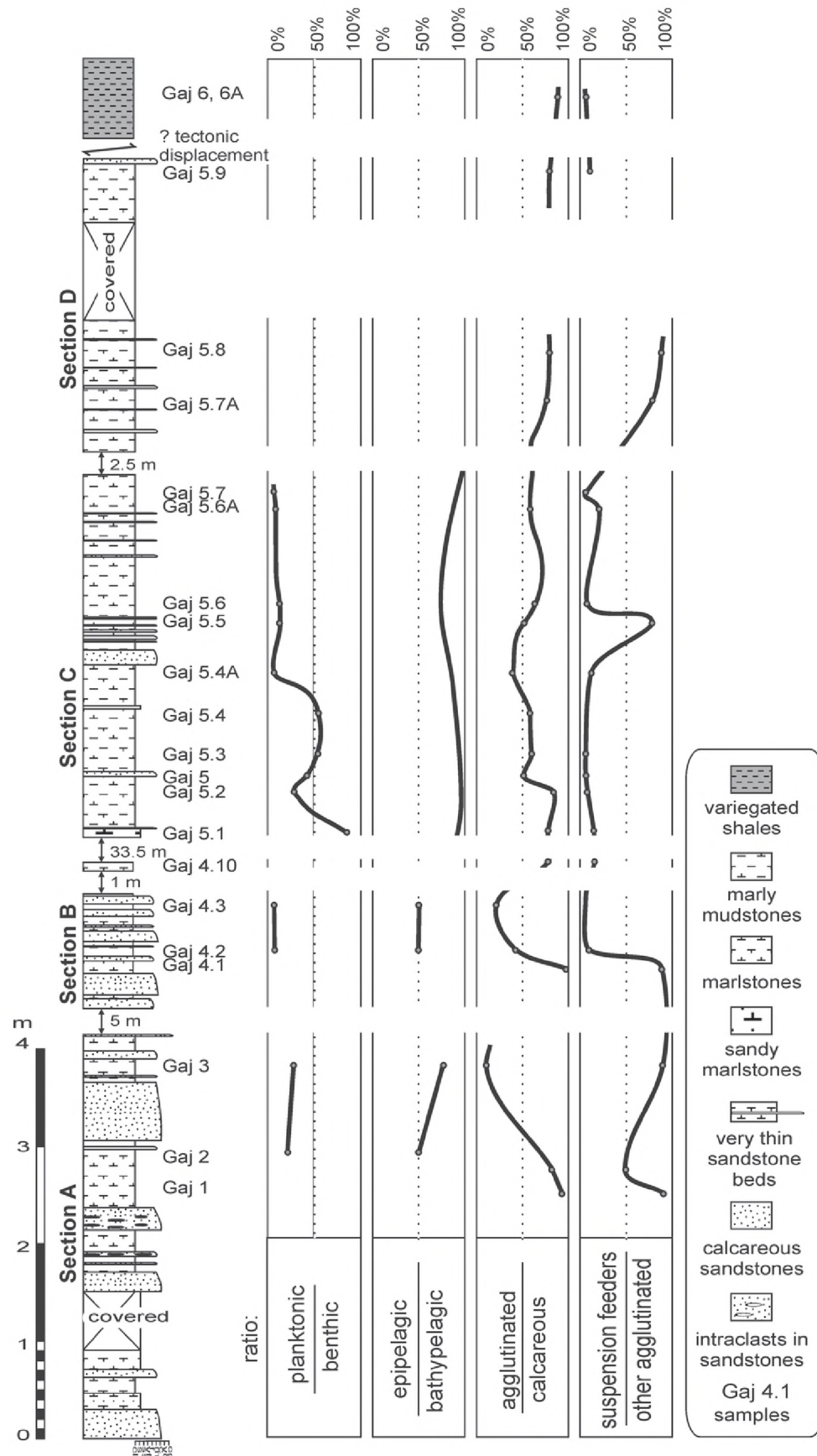


Fig. 6. Quantitative analysis of the studied foraminiferal assemblages.

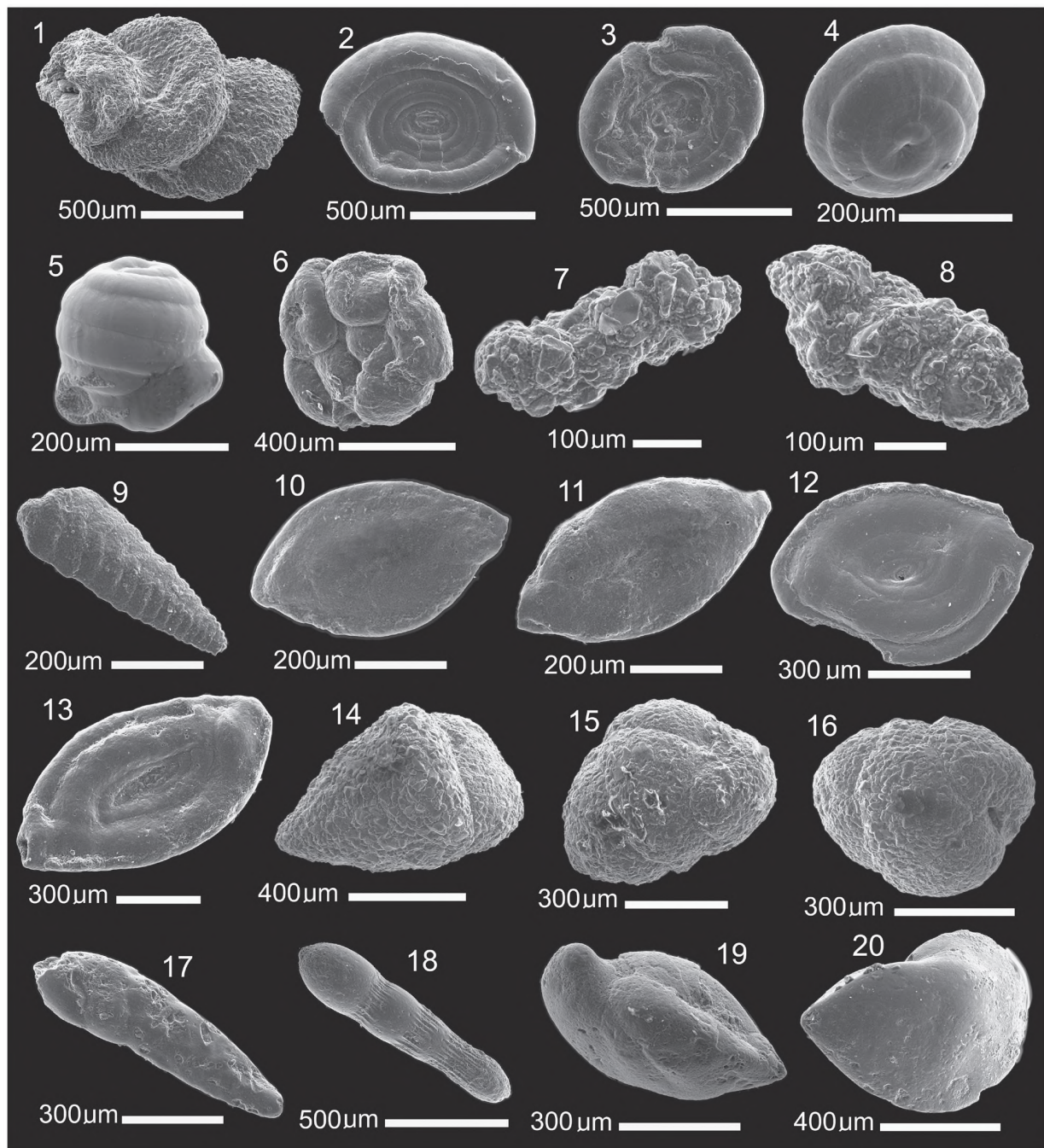


Fig. 7. Benthic foraminiferids from the Gaj section. 1 — *Hormosina velascoensis* (Cushman), sample Gaj 5.8. 2, 3 — *Ammodiscus* sp., 2 — sample Gaj 5.3, 3 — sample Gaj 6. 4, 5 — *Glomospira charoides* (Parker & Jones), 4 — sample Gaj 5.3, 5 — sample Gaj 6. 6 — *Congolophragmium irregularis* (White), sample Gaj 6. 7 — *Karrerulina horrida* (Mjatluk), sample Gaj 6A. 8 — *Karrerulina conversa* (Grzybowski), sample Gaj 6A. 9 — *Spiroplectammina spectabilis* (Grzybowski), sample Gaj 5.4. 10, 11 — *Rzehakina epigona* (Grzybowski), sample Gaj 5.2. 12, 13 — *Rzehakina fissistomata* (Grzybowski), sample Gaj 5.9. 14 — *Dorothia oxycona*, sample Gaj 5.8. 15, 16 — *Arenobulimina dorbignyi* (Reuss), sample Gaj 5.6A. 17 — *Coryphostoma cf. plaia* (Carsey), sample Gaj 5. 18 — *Nodosaria* sp., sample Gaj 5.3. 19 — *Saracenaria cf. triangularis* (d'Orbigny), sample Gaj 5.4. 20 — *Lenticulina* sp., sample Gaj 5.4A.

According to the results of cluster analysis of significant Campanian–Maastrichtian foraminiferal associations (Gasiński 1998), the considered associations fit within the “transitional zone” between the Boreal and Tethyan provinces (cf. Gasiński 1997, 1998; Marcinowski & Gasiński 2002). In comparison to the Maastrichtian foraminiferal assemblages from the Andry-

chów Klippen marls regarded as typical “transitional” biota between Boreal and Tethyan domains (cf. Gasiński 1998), the described assemblages do not contain some planktonic genera (e.g. *Rugoglobigerina*), that are diagnostic of the Boreal province (cf. Scheibnerova 1971; Sliter 1972, 1977; Gasiński 1997). According to Olsson & Wise (1987), *Contusotruncana*

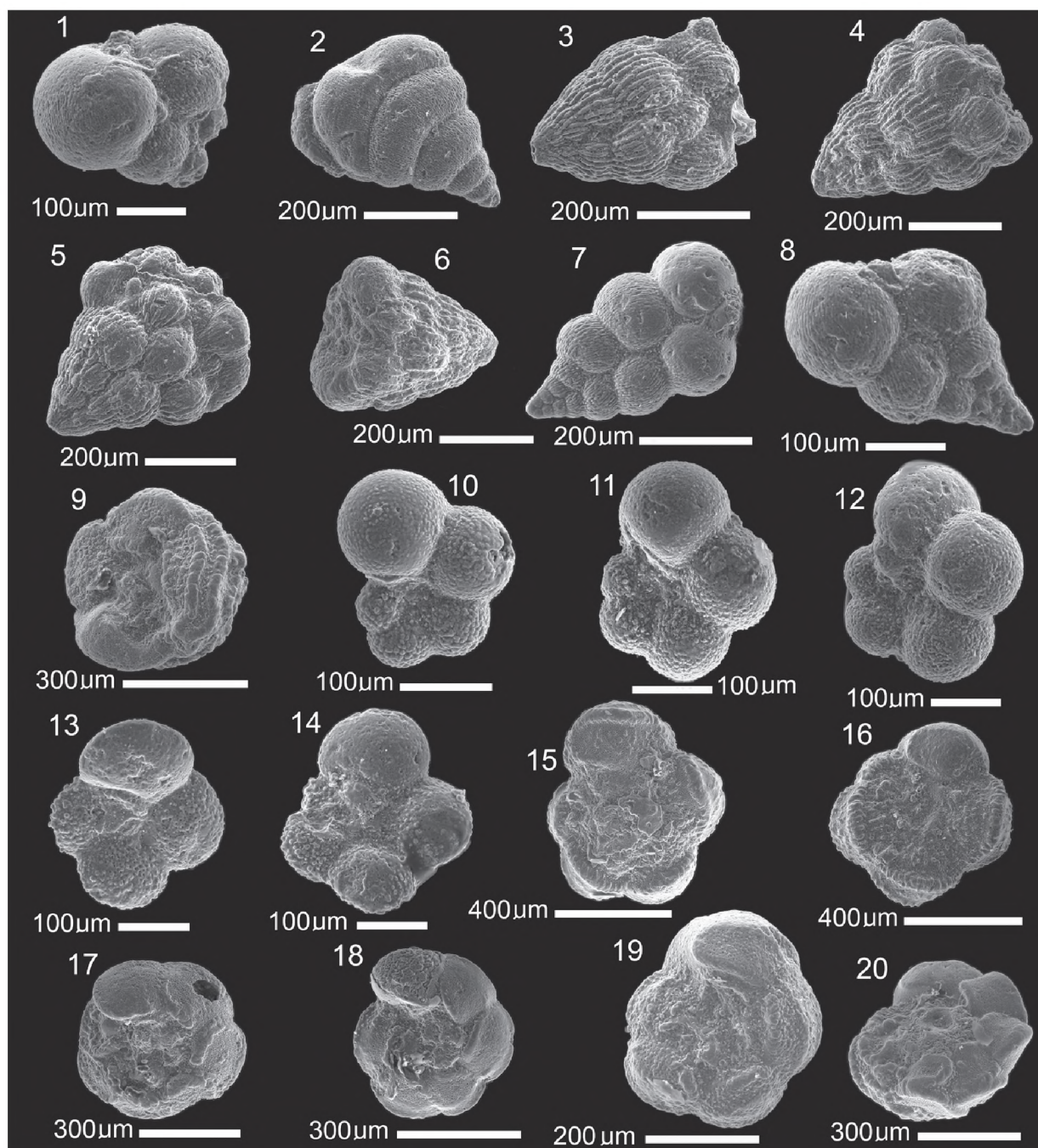


Fig. 8. Planktonic foraminiferids from the Gaj section. 1, 7 — *Heterohelix striata* (Ehrenberg), sample Gaj 5. 2 — *Pseudotextularia elegans* (Rzehak), sample Gaj 5. 3–6 — *Racemiguembelina fructicosa* (Egger), sample Gaj 5. 8 — *Heterohelix navarroensis* Ehrenberg, sample Gaj 5. 9 — *Contusotruncana contusa* (Cushman), sample Gaj 5. 10 — *Hedbergella monmouthensis* (Olsson), sample Gaj 5. 11–12 — *Hedbergella holmdelensis* Olsson, sample Gaj 5. 13 — *Globotruncanella havanensis* (Voorwijk), sample Gaj 5. 14 — *Globotruncanella petaloidea* (Gandolfi), sample Gaj 5. 15, 16 — *Abathomphalus mayaroensis* (Bolli), 15 — sample Gaj 5, 16 — sample Gaj 5.4. 17 — *Globotruncanella stuarti* (de Lapparent), sample Gaj 5.4. 18, 20 — *Globotruncana bulloides* Vogler, sample Gaj 3. 19 — *Globotruncana arca* Cushman, sample Gaj 5.7.

contusa and *Globotruncana arca* (species noted in the studied assemblages) are characteristic of the transitional domain. Malmgren (1991) stated that *Abathomphalus mayaroensis*, *Pseudotextularia elegans* and *Globotruncana arca* characterize the so-called “warm transitional subassemblage”. However, Malmgren also mentioned rugoglobigerinids among this

“subassemblage”, but they are absent in the studied material. The compositions of the benthic foraminiferal assemblages are also different than those of the Boreal province. For instance, *Stensioeina* and *Bolivinoidea*, genera characteristic for the transitional zone are absent in the studied material. Kotlarczyk (1978, 1985) listed such genera from the Wiar and

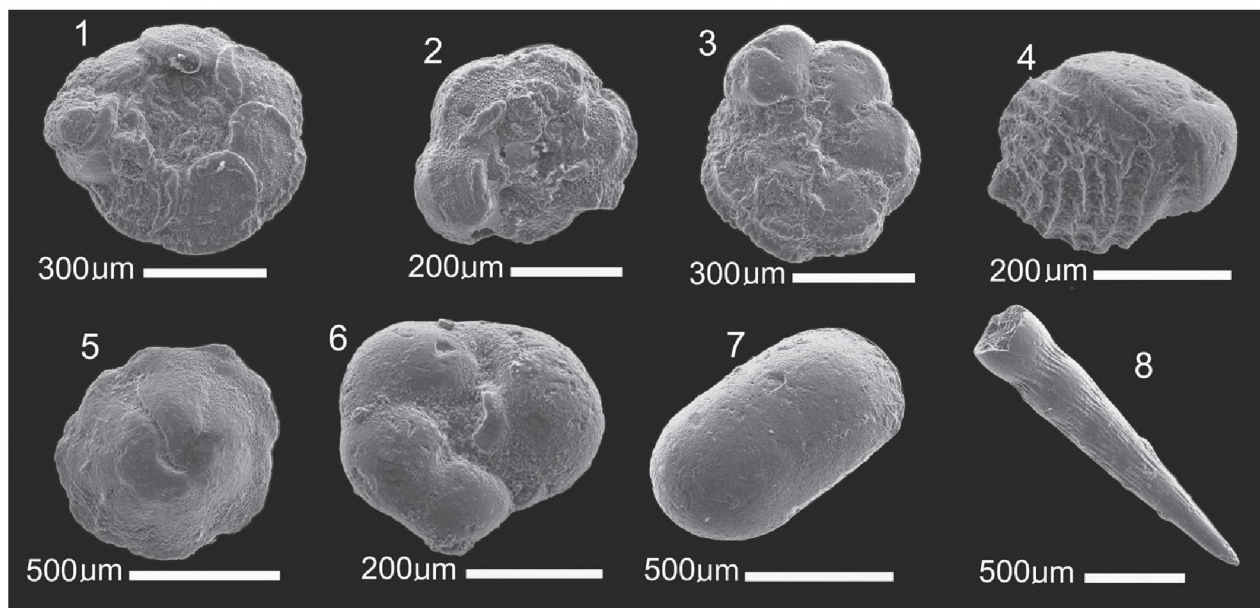


Fig. 9. Other microfossils from the Gaj section. 1 — *Globotruncanita stuartiformis* Dalbiez, sample Gaj 5.2. 2 — *Globotruncana linneiana* (de Lapparent), sample Gaj 3. 3 — *Globotruncana arca* Cushman, sample Gaj 5. 4 — *Aragonia ouezzensis* (Rey), sample Gaj 5. 5 — *Cibicides* sp., sample Gaj 5.4. 6 — *Quadrimorphina allomorphinoides* (Reuss), sample Gaj 5.4. 7 — Ostracoda, sample Gaj 5.4. 8 — ?*Nodosaria* sp., sample Gaj 5.4A.

Leszczyny Members. However, the problem of migration processes of microfauna between Tethyan Carpathian basins and Boreal domain is still unsolved.

The connection between the Skole Basin and the adjacent epicontinental sea has been suggested for quite some time. Wawryk (1939) noted a similarity of the more or less coeval sediments of the so-called Łopuszka Marls and Węgierka Marls (about 20 km E of the studied section) to the marls exposed near Lviv (the so-called Lviv Opoka). Kotlarczyk (1988) mentioned that the Leszczyny Member marls resemble the Upper Cretaceous marls from the Eastern European Platform. These suggestions are confirmed by the studied foraminiferal assemblage composition.

The possible migration gates of biota between the Boreal and Tethyan provinces during the Late Cretaceous have been discussed by Hanzliková (1972), Fuchs & Wessely (1996), Gasiński (1998) and Marcinowski & Gasiński (2002). The processes of migration and strategies of foraminiferal “migrants” have been suggested by Gasiński (1997, 1998) and Marcinowski & Gasiński (2002). In the later publication the so-called “Lviv Gate” is suggested as the migration pathway to the Carpathian basins from the North (Marcinowski & Gasiński 1992, p. 109).

Conclusions

1. The studied deposits of the Ropianka Formation in the Gaj section are here correlated with the Maastrichtian (part of the Gansserina gansseri Zone and the Abathomphalus mayaroensis Zone). The uppermost part of the section is dated to the Paleocene. The K/T boundary is located within a 3 m thick part of the Gaj section.

2. Foraminiferal assemblage composition indicates fluctuations in organic matter flux to the marginal part of the Skole Basin floor in the studied interval.

3. The studied foraminiferal assemblages are typical of the “transitional zone” between the Tethyan and the Boreal domains.

Acknowledgments: The authors greatly appreciate Janusz Kotlarczyk (Academy of Mining and Metallurgy; Cracow) for his constructive criticism and helpful remarks. We would like to thank Michael A. Kaminski (University College London) and Ryszard Marcinowski (Warsaw University) for their reviewer comments and suggestions. Jagiellonian University provided the support (DS funds).

References

- Bieda F., Geroch S., Koszarski L., Książkiewicz M. & Żytko K. 1963: Stratigraphie des Karpates externes polonaises. *Biul. Inst. Geol.* 181, 1–210.
- Bromowicz J. 1974: Facial variability and lithological character of Inoceraman Beds of the Skole Nappe between Rzeszów and Przemyśl. *Prace Geologiczne, Polska Akademia Nauk, Oddział w Krakowie, Komisja Nauk Geologicznych* 84, 1–83 (in Polish with English summary).
- Bukowy S. 1956: Observations on sedimentation of the Babica clays (Palaeocene) in the Middle Carpathians. *Bull. Polish Acad. Sci. Cl.* 3, 4(9), 631–635.
- Bukowy S. 1957: Remarks on the sedimentation of the Babica clays. *Rocznik Polskiego Towarzystwa Geologicznego* 26 (for 1956), 147–155 (in Polish).
- Bukowy S. & Geroch S. 1957: On the age of exotic conglomerates at Kruhel Wielki near Przemyśl (Carpathians). *Ann. Soc. Geol. Pol.* 26, 297–329 (in Polish with English summary).

- Burzewski W. 1966: Baculites marls on the lithostratigraphy background of the upper Inoceranian Beds of the Skiba Carpathians. *Zeszyty Naukowe AGH, Geol.* 7, 89–115 (in Polish).
- Caron M. 1985: Cretaceous planktonic foraminifera. In: Bolli H.M., Saunders J. & Perch-Nielsen K. (Eds.): *Plankton stratigraphy*. Cambridge University Press, Cambridge, 17–86.
- Friedberg W. 1900: Geological investigations of the vicinity of Rzeszów and Łańcut. *Kosmos* 24, 289–311 (in Polish).
- Friedberg W. 1901: Foraminiferids of the Inoceranian Beds of the vicinity of Rzeszów and Dębica. *Rozpr. Wydziału Matematyczno-Przyrodniczego Akademii Umiejętności, Seria* 3, Tom 1, Dział B, Nauki Biologiczne 41, 601–668 (in Polish only).
- Friedberg W. 1903: Geological Atlas of Galicia. *Tekst do Zeszytu Szesnastego*. Wydawnictwa Komisji Fizyograficznej Akademii Umiejętności, Kraków, 1–147 (in Polish only).
- Friedberg W. 1908: Small contribution to the Inoceranian Beds fauna. *Sprawozdanie Komisji Fizyograficznej Akademii Umiejętności* 42, 58–63 (in Polish only).
- Fuchs R. & Wessely G. 1996: The autochthonous Cretaceous at the southern edge of the Bohemian Massif (Austria). In: Wessely G. & Liebl (Eds.): *Oil and gas in Alpine thrustbelts and basins of Central and Eastern Europe*. *Geol. Soc. London, European Assoc. Geosci. and Engineers, Spec. Publ.* 5, 249–253.
- Gasiński M.A. 1997: Tethyan-Boreal connection: influence on the evolution of mid-Cretaceous planktonic foraminiferids. *Cretaceous Research* 18, 505–514.
- Gasiński M.A. 1998: Campanian–Maastrichtian palaeoecology and palaeobiogeography of the Andrychów Klippes, Outer Carpathians, Poland. *Uniwersytet Jagielloński, Rozprawy Habiliacyjne* 333, 1–90.
- Gasiński M.A., Jugowiec M. & Ślaczka A. 1999: Late Cretaceous foraminiferids and calcareous nannoplankton from the Węglówka Marls (Subsilesian Unit, Outer Carpathians, Poland). *Geol. Carpathica* 50, 1–11.
- Gasiński M.A., Leśniak T. & Piotrowski M. 2001: Latest Maastrichtian foraminiferal *Athamphalus mayaroensis* Zone in the Subsilesian Unit (Polish Outer Carpathians). *Bull. Polish Acad. Sci., Earth Sci.* 49, 89–97.
- Gasiński M.A., Leśniak T. & Wróbel A. 2003: Biostratigraphy and palaeoenvironmental analysis of the Żegocina Marls in the Żegocina Tectonic Window (Subsilesian Unit, Polish Outer Carpathians). *Bull. Polish Acad. Sci., Earth Sci.* 51, 1–9.
- Gedl E. 1999: Lower Cretaceous palynomorphs from the Skole Nappe (Outer Carpathians, Poland). *Geol. Carpathica* 50, 75–90.
- Geroch S. & Kotlarczyk J. 1963: Remarks about the age of the Babice Clay marls from the Bircza vicinity. *Przegl. Geol.* 11, 286–287 (in Polish).
- Geroch S. & Nowak W. 1984: Proposal of zonation for the Late Tithonian–Late Eocene based upon arenaceous foraminifera from the Outer Carpathians, Poland. In: Oertli (Ed.): *Benthos '83*: 2nd International Symposium on Benthic Foraminifera (Pau, France). *Elf-Aquitaine, ESSO REP and Total CFP, Pau & Bordeaux*, 225–239.
- Geroch S., Jednorowska A., Książkiewicz M. & Liszkowa J. 1967: Stratigraphy based upon microfauna in the Western Polish Carpathians. *Biul. Inst. Geol.* 211, 186–282.
- Geroch S., Kryszowska-Iwaszkiewicz M., Michalik M., Prochazka K., Radomski A., Radwański Z., Unrug Z., Unrug R. & Wieczorek J. 1979: Sedimentation of the Wegierka marls. *Ann. Soc. Geol. Pol.* 49, 105–133 (in Polish with English summary).
- Gradstein F., Ogg J. & Smith A. 2004: A geologic time scale. *Cambridge University Press*, Cambridge, 1–589.
- Grzybowski J. 1903: Geological Atlas of Galicia. *Tekst do Zeszytu Czternastego*. Wydawnictwa Komisji Fizyograficznej Akademii Umiejętności, Kraków, 1–91 (in Polish only).
- Gucik S. 1962: Geology of the northern part of the Skole unit between Pruchnik and Ujkowice. *Kwart. Geol.* 4, 794–795 (in Polish only).
- Gucik S. 1987: Explanations to the Geological Map of Poland 1:50,000. Sheet Krzywcz. *Wydawnictwa Geologiczne*, Warszawa, 1–77 (in Polish only).
- Gucik S. & Wójcik A. 1982: Explanation to the Geological Map of Poland 1:200,000. Sheet Przemyśl–Kalniki. *Wydawnictwa Geologiczne*, Warszawa, 1–91 (in Polish only).
- Haczewski G. 1986: The place and role of marker lithological horizons in litho- and chronostratigraphy. *Przegl. Geol.* 34, 247–250 (in Polish with English summary).
- Hanzliková E. 1969: The Foraminifera of the Frydek Formation (Senonian). *Sbor. Geol. Věd* 11, 7–84.
- Hanzliková E. 1972: Carpathian Upper Cretaceous Foraminifera of Moravia (Turonian–Maastrichtian). *Rozpr. Ústř. Úst. Geol.* 39, 1–160.
- Hilber V. 1885: Randtheil der Karpathen bei Dębica, Ropczyce und Łańcut. *Jb. Geol. Reichsanst.* 35, 407–428.
- Jones R.W. & Charnock M. 1985: “Morphogroups” of agglutinated foraminifera. Their life position and feeding habits and potential applicability in (paleo) ecological studies. *Rev. Paleobiologie* 4, 311–320.
- Kaminski M.A. & Gradstein F.M. 2005: Atlas of Paleogene cosmopolitan deep-water Foraminifera. *Grzybowski Found. Spec. Publ.* 10, 1–547.
- Kaminski M.A. & Kuhnt W. 1995: Tubular agglutinated foraminifera as indicators of organic carbon flux. In: Kaminski M.A., Geroch S. & Gasiński M.A. (Eds.): *Proceedings of the Fourth International Workshop on Agglutinated Foraminifera*. *Grzybowski Found. Spec. Publ.* 3, 141–144.
- Kollmann H.A. & Zapfe H. (Eds.) 1992: New aspects on Tethyan Cretaceous fossil assemblages. *Österr. Akad. Wiss. Schriftenreihe der Erdwissenschaftlichen Kommissionen* 9, 1–240.
- Kotlarczyk J. 1978: Stratigraphy of the Ropianka Formation or of Inoceranian Beds in the Skole Unit of the Flysch Carpathians. *Prace Geol., Polska Akad. Nauk, Oddział w Krakowie, Komisja Nauk Geologicznych* 108, 1–82 (in Polish with English summary).
- Kotlarczyk J. 1979: Stratigraphy of the Ropianka Formation of the Skole unit. *Materiały Terenowej Konferencji Naukowej w Przemyślu, Przemyśl*, 28–29 czerwca 1979 r. *Sekcja Sedymetologiczna Polskiego Towarzystwa Geologicznego*, Kraków, 7–16 (in Polish).
- Kotlarczyk J. 1985: An outline of the stratigraphy of marginal tectonic units of the Carpathian Orogen in the Rzeszów–Przemyśl area. In: Kotlarczyk J. (Ed.): *Geotraverse Kraków–Baranów–Rzeszów–Przemyśl–Ustrzyki Dolne–Komańcza–Dukla. Guide to excursion 4. Carpatho-Balkan Geological Association XIII Congress. Cracow, Poland 1985*. *Geol. Inst.*, Warszawa, 39–63.
- Kotlarczyk J. 1988: Outline of the stratigraphy of the marginal tectonic units of the Carpathian orogen In: Kotlarczyk J., Pękala K. & Guzik S. (Eds.): *Przewodnik 59 Zjazdu Polskiego Towarzystwa Geologicznego, Karpaty Przemyskie*, 16–18 września 1988. *Wydawnictwo AGH*, Kraków, 23–62 (in Polish).
- Kotlarczyk J., Jerzmańska A., Świdnicka E. & Wiszniowska T. 2007: A framework of ichthyofaunal ecostratigraphy of the Oligocene–Early Miocene strata of the Polish Outer Carpathian Basin. *Ann. Soc. Geol. Pol.* 76, 1–111.
- Liszkowa J. 1956: Microfauna of the Subsilesian unit. *Przegl. Geol.* 10, 463–469 (in Polish).
- Liszkowa J. & Morgiel J. 1981: Microfauna of the Frydek type in Outer Carpathians, Poland. *Biul. Inst. Geol.* 331, 83–100 (in Polish with English summary).
- Malata T. 1996: An analysis of formal lithostratigraphic divisions and a proposition of the subdivision of the Skole Unit of the Polish Flysch Carpathians. *Przegl. Geol.* 44, 509–514 (in Polish).
- Malata T. 2001: The Skole Unit east of Rzeszów. *Posiedzenia*

- Naukowe Państwowego Instytutu Geologii*, 57(9), 60–63 (in Polish).
- Marcinowski R. & Gasiński M.A. 2002: Cretaceous biogeography of epicratonic Poland and Carpathians. In: Michalik J. (Ed.): Tethyan/Boreal Cretaceous Correlation. Mediterranean and Boreal Cretaceous paleobiogeographic areas in Central and Eastern Europe. *Veda, Publishing House of the Slovak Academy of Sciences*, Bratislava, 95–115.
- Morgiel J. & Żgiet J. 1961: Upper Cretaceous deposits at Dydynia borehole (Sanok Carpathians). *Kwart. Geol.* 5, 993–994 (in Polish).
- Nederbragt A.J. 1991: Late Cretaceous biostratigraphy and development of Heterohelicidae (planktic foraminifera). *Micropaleontology* 37, 329–372.
- Olsson R.K. & Nyong E.E. 1984: A paleoslope model for Campanian–lower Maestrichtian foraminifera of New Jersey and Delaware. *J. Foram. Res.* 14, 50–69.
- Olsson R.K. & Wise S.W. 1987: Upper Maestrichtian to middle Eocene stratigraphy of the New Jersey slope and coastal plain. In: van Hinte J.E., Wise S.W. et al. (Eds.): *Initial Reports of the Deep Sea Drilling Project* 93, 1243–1365.
- Olsson R.K., Hemleben C., Berggren W.A. & Huber B.T. 1999: Atlas of Paleocene planktonic foraminifera. *Smithsonian Contributions to Paleobiology* 85, 1–252.
- Paul K.M. 1869: Die geologischen Verhältnisse des nördlichen Sarroser und Zempliner Comitates. *Jb. K.-Kön. Geol. Reichsanst.* 19, 156–280.
- Premoli-Silva I. & Rettori R. (Eds.) 2002: Practical manual of Cretaceous planktonic Foraminifera. International School on Planktonic Foraminifera, Perugia 18–22 February, 2002. *Dipartimento di Scienza della Terra, Università di Perugia*, Perugia, 1–462.
- Premoli-Silva I. & Verga D. 2004: Practical manual of Cretaceous planktonic Foraminifera. International School on Planktonic Foraminifera. 3rd Course: Cretaceous. Verga et Rettori eds. *Universities of Perugia and Milano*, Tipografia Pontfelcino, Perugia, 1–283.
- Rajchel J. 1990: Lithostratigraphy of the Upper Paleocene and Eocene deposits in the Skole Unit. *Zeszyty Naukowe AGH, Geol.* 48, 1–112 (in Polish with English summary).
- Rajchel J. & Uchman A. 1998: Ichnological analysis of an Eocene mixed marly-siliciclastic flysch deposits in the Nienadowa Marls Member, Skole Unit, Polish Flysch Carpathians. *Ann. Soc. Geol. Pol.* 68, 61–74.
- Robaszynski F. & Caron M. 1995: Foraminifères planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. *Bull. Soc. Géol. France* 6, 681–692.
- Robaszynski F., Caron M., Gonzales J.M. & Wonders A.H. (Eds.) 1984: Atlas of Late Cretaceous globotruncanids. *Rev. Micropaleontologie* 26, 145–305.
- Scheibnerova V. 1971: Foraminifera and the Mesozoic biogeoprovinces. *Geol. Surv. New South Wales* 13, 135–174.
- Sliter W.V. 1972: Upper Cretaceous planktonic foraminiferal zoogeography and ecology-eastern Pacific margin. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 12, 15–31.
- Sliter W.V. & Baker R.A. 1972: Cretaceous bathymetric distribution of benthic foraminiferids. *J. Foram. Res.* 2, 167–183.
- Szymakowska F. 1961: A new locality with “Palaeocene” sediments from the Skole Unit at Kamienica Dolna and Gorzejowa (Carpathians). *Kwart. Geol.* 5, 613–629 (in Polish with English summary).
- Ślaczka A. & Kaminski M.A. 1998: A guidebook to excursions in the Polish Flysch Carpathians. *Grzybowski Found. Spec. Publ.* 6, 11–71.
- Ślaczka A. & Miziolek M. 1995: Geological setting of Ropianka Beds in Ropianka (Polish Carpathians). *Ann. Soc. Geol. Pol.* 65, 29–41.
- Tietze E. 1883: Beiträge zur Geologie von Galizien. *Jb. K.-Kön. Geol. Reichsanst.* 33, 443–560.
- Tshakreen S.O. & Gasinski M.A. 2004: Cretaceous-Paleogene boundary problem in Libya: the occurrence of the foraminiferal species *Abathomphalus mayaroensis* (Bolli) in the Western Sirt Basin. *Geol. Quart.* 48, 77–82.
- Uhlir V. 1888: Ergebnisse geologischer Aufnahmen in den westgalizischen Karpathen. I. Theil. Die Sandsteizone zwischen dem penninischen Klippenzuge und dem Nordrande. *Jb. K.-Kön. Geol. Reichsanst.* 38, 83–264.
- Vialov O.S., Dabagian N.W. & Zhurakovsky A.G. 1967: Description of the Cretaceous Flysch section along the Dniestr river between Tershevo and Spas. *Geol. J.* 27, 3–15 (in Ukrainian).
- Wawryk W. 1930: L’analyse pétrographique de la marne de Lwów et des marnes de Łopuszka et de Węgierka. *Kosmos* A, 54, 889–915 (in Polish with French summary).
- Wdowiarz S. 1936: Report of geological investigations in the Carpathians in 1936 in the area of SE from Rzeszów. *Spraw. Państw. Inst. Geol.* 45, 20–22 (in Polish).
- Wdowiarz S. 1949: Structure géologique des Karpates Marginales au sud-est de Rzeszów. *Biul. Państw. Inst. Geol.* 11, 1–51.
- Wdowiarz S., Wieser T., Szczurowska J., Morgiel J. & Szotowa W. 1974: Geological structure of the Skole unit and its basement in the column of the Cisowa IG 1 Borehole. *Biul. Inst. Geol.* 18, 1–94 (in Polish with English summary).
- Zhurakovsky A.G. 1971: Stratigraphy of the Cretaceous deposits of the northern slope of the Ukrainian Carpathians. *Materiale po Geologii i Neftegazonosnosti Ukrainy* 26, 85–96 (in Russian).
- Żytka K. & Zimnal Z. 1997: Explanations to the Geological Map of Poland 1:50,000. Sheet Ustrzyki Dolne. *Wydawnictwa Geologiczne*, Warszawa, 1–44 (in Polish).